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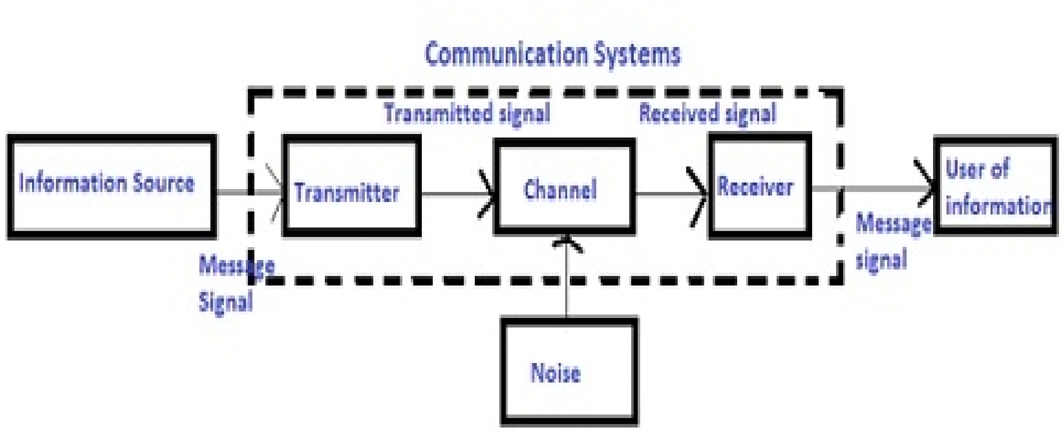
Class 12 Physics-

Communication Systems

Communication System:A communication system is a setup used in the transmission of information from one place to another place.

The general block diagram of communication system is depicted below:



As we see here, the basic elements of communication includes transmitter, Channel and the receiver. The transmitter and the receiver may be located geographically at different places. The Channel connects the transmitter and the receiver.

Information Source – The source produces signal of the information which needs to be communicated.

Input transducer:a transducer is a device that converts one form of energy into another.The message from information source may or may not be in electrical form.An input transducer is used to convert a non electrical signal to time varying electrical signal. MICROPHONE IS EXAMPLE OF input TRANSDUCER

Signal – Information in electrical form suitable for transmission is called signal.

Transmitter – Converts the source signal into suitable form for transmission through the channel.The functions of transmtter are modulation and amplification.

Channel – The channel connecting the transmitter and the receiver is a medium. The channel can be in the form of wires, cables or wireless.the function of channel to provide physical connection between transmitter and reciever.

Noise – When the transmitted signal propagates along the channel, it may get distorted due to channel imperfection.Thus, noise refers to unwanted signals that tend to disturb the process of communication from the transmitter to the receive. Mostly noise is introduced in channel during transmission.

Receiver – Due to noise and other factors, the distorted version of signal arrives at the receiver. The receiver has to reconstruct the signal into recognisable form of the original message for delivering it to the user. The signal at the receiver forms the output.this process is done by demodulation or detection.

Output transducer:The output transducer converts back the electrical signal to non electrical.

speaker is example of output transducer

Modes of communication

Point to point communication – There is a single link between the transmitter and the receiver. Communication takes place between single transmitter and receiver.Example – Telephone


Broadcast mode – There are large number of receivers though information is sent by a single transmitter.Example – Television and Radio

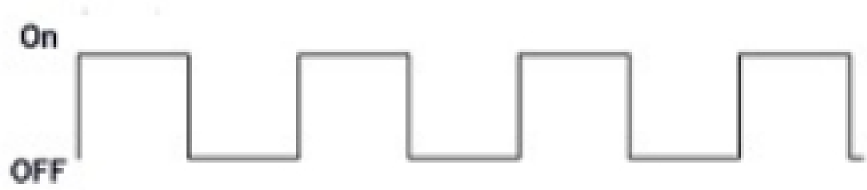

Signal Types – Information in electrical form suitable for transmission called signal, is of two types

Analog signal –

- Continuous variations of voltage and current. Hence, single valued functions of time.
- Sine wave is a fundamental analog signal
- Example – Sound and picture signals in television

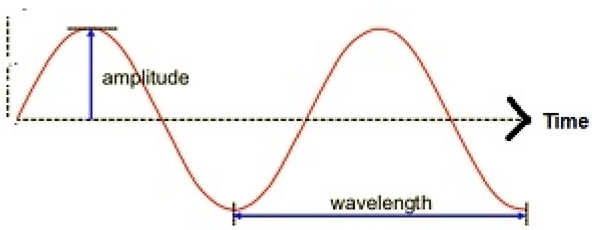
Digital signal –

- Digital step value based
- Binary system where 0 represents low level and 1 represents high level is used
- Universal digital coding methods like BCD – Binary Coded Decimal and ASCII – American Standard Code of Information Interchange is used in common



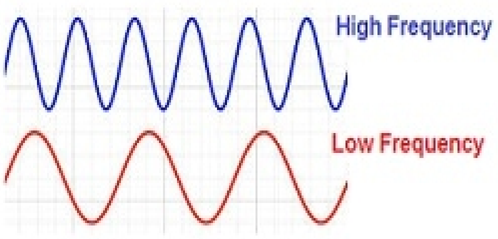
Amplitude –

The maximum extent of vibration or oscillation from the position o fequilibrium.



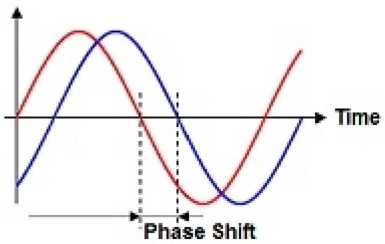
Frequency –

The frequency is the number of waves which pass a fixed place in a given amount of time.



Phase –

The two waves depicted below have a phase difference indicated by the phase shift which is the fraction of the wave cycle which has elapsed relative to the origin.



Attenuation – The loss of strength of the signal while propagating through a medium is known as attenuation.

Amplification – The process of increasing the amplitude of the signal by using an electronic circuit is called amplification. Hence, it compensates the attenuation of the signal.

Range – It is the largest distance between the source and the destination upto which the signal is received with sufficient strength.

Bandwidth – It refers to the frequency range for which the equipment operates.Bandwidth is defined as frequency range over which an information signal is transmitted.Bandwidth is portion of electromagnwtic spectrum occupied by a signal.It is difference between upper and lower frequency limits of a signal.

The range of music signal is from 20Hz to 15KHz.

Therefore bandwidth of music signal is f_2-f_1 =15Khz-20Hz=15000 Hz-20 Hz=14980 Hz

S no.	Type of signal	Frequency range	Bandwidth
I.	Speech for telephony	300Hz -3100Hz	2800Hz
II.	Music signal	20Hz-20Khz	≈ 20Khz
III.	Tv signal	0 -6Mhz	6Mhz
IV.	VHF (very high frequency tv signals)	54-72Mhz	16 Mhz

V.	DIGITAL DATA		INFINITE BANDWIDTH
VI.	UHF(ultra high frequency tv signal	420-890Mhz	470Mhz
VII.	Cellular mobilephones	840-935Mhz	95 Mhz

Bandwidth of transmission medium:commonly used communication channels are co axial cables,optical fibre,free space etc.The bandwidth of some transmission mediums are given below:

FREE SPACE:Communication through free space is possible for radio, tv,mobile phones,satellite phones having frequency range from 580 Khz to 6.5Ghz .

COaxial cables:The bandwidth of signals used in coaxil cables is 750 Mhz.

Optical fibre:The bandwidth of an optical fibre is above 10^{11}Hz.

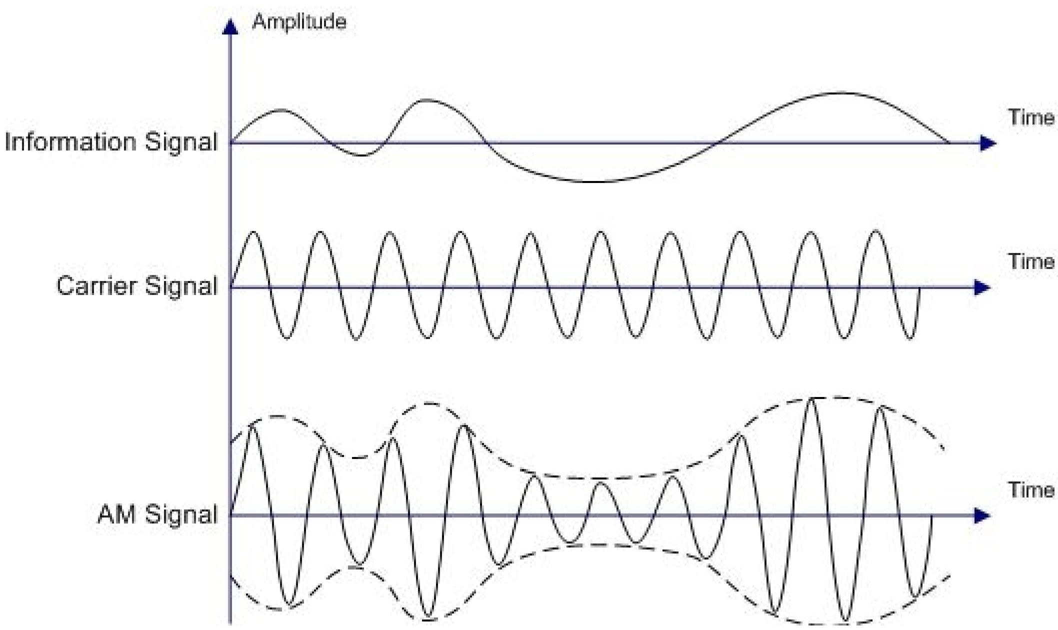
Modulation – If the information signal is of low frequency, it cannot be transmitted to long distances. Hence, at transmission point, it is superimposed on high frequency wave. This high frequency wave acts as a carrier of information.

The process in which some characteristic of carrier wave is changed in accordance with the modulating signal(message signal) is called modulation.

Sinusoidal wave modulation:

There are 3 types of modulation, namely 1. Amplitude modulation 2.Frequency modulation and 3. Phase modulation

Amplitude modulation –



. In amplitude modulation, the amplitude of the carrier wave is varied in accordance with the amplitude of the information signal or modulating signal.

Mathematical equation of AM wave:

Let *$m(t) = A_m\cos\omega_m t$ ……………………….(1)*

be the information signal (modulating signal) with angular frequency $\omega_m = 2\pi f_m$

A_m = Amplitude of modulating signal

Let *$C(t)$* = $A_c\sin\omega_c t$ -------------------------------*(2)*

be the carrier signal with angular frequency $\omega_m=2\pi f_c$

A_c = Amplitude of carrier wave

The instantneous voltage of modulated signal is given by

$S(t) = (A_c+ A_m\cos\omega_m t) \sin \omega_c t$ -------------------------------*(3)*

$$s(t) = A_c[1+\frac{A_m}{A_c}\cos w_m t]\sin w_c t$$

But

$$\frac{A_m}{A_c} = m_a$$

Called modulation index

Therefore, $s(t) = A_c[1+m_a\cos w_m t]\sin w_c t$

$s(t) = A_c[\sin w_c t + m_a \sin w_c t \cos w_m t]$

$$s(t) = A_c \sin w_c t + \frac{m_a A_c}{2} 2 \sin w_c t \cos w_m t$$

$$s(t) = A_c \sin w_c t + \frac{m_a A_c}{2}\sin(w_c + w_m)t + \frac{m_a A_c}{2}\sin(w_c - w_m)t$$

Which is an AM wave.

The above equation shows that the amplitude modulated signal consists of
Carrier wave of frequency ω_c
Sinusoidal wave of frequency $(\omega_c-\omega_m)$
Sinusoidal wave of frequency $(\omega_c+\omega_m)$
The two additional waves are called side bands. The frequency of these bands are called side band frequencies
Frequency of lower side band = $(\omega_c-\omega_m)$
Frequency of upper side band = $(\omega_c+\omega_m)$

The band width of the AM wave is Frequency of upper sideband minus Frequency of lower sideband *$(\omega_c+\omega_m) - (\omega_c-\omega_m) = 2\omega_m$ (Twice the frequency of modulating signal)*

Problem – The frequencies of two side bands in an AM wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation ?**(CBSE 2017 Set 1)**

Solution - Given $(\omega c+\omega m) = 660$ kHz ; $(\omega c-\omega m) = 640$ kHz

- *$(\omega c+\omega m) - (\omega c-\omega m) = 2\ \omega m = 660 – 640 = 20$ kHz*

Hence, frequency of modulating signal $\omega m = 10$ kHz

- *Now, $(\omega c+\omega m) = 660$ kHz, $(\omega c+10) = 660$ kHz, Hence, frequency of carrier wave $\omega c = 660 – 10 = 650$ kHz*
- *The band width of the AM wave is Frequency of upper side band minus Frequency of lower side band $(\omega c+\omega m) - (\omega c-\omega m) = 2\omega m$*

Hence, $2\ \omega m = 20$ kHz

Problem – An audio signal of amplitude 0.1 V is used in amplitude modulation of a carrier wave of amplitude 0.2 V. Calculate the modulation index.

Solution –

We know that

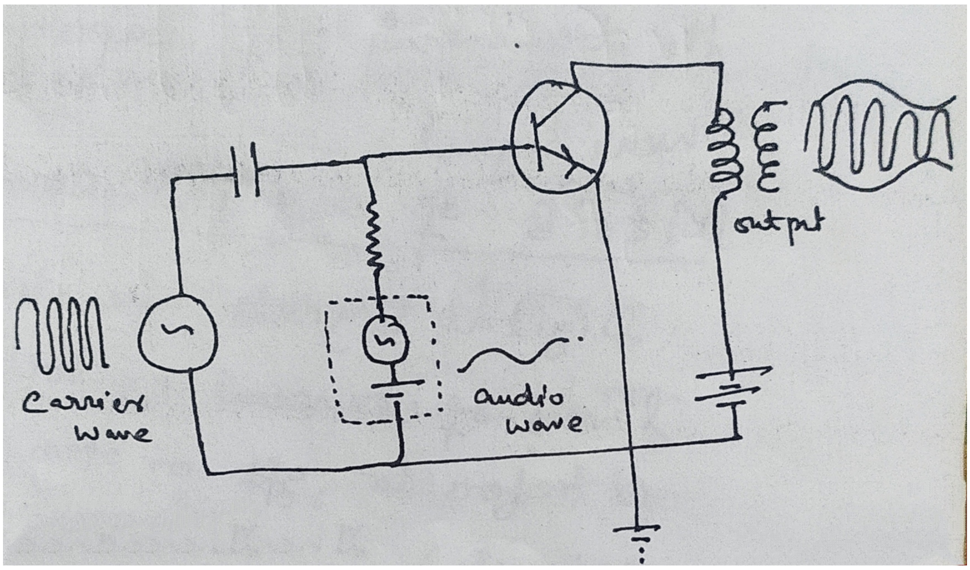
$A_m / A_c = m_a$, given $A_m = 0.1$ V , $A_c = 0.2$ V

Therefore,

$m_a = 0.1 / 0.2 = 0.5$

Production of AM wave

In case of amplitude modulation,the amplitude of AM wave increases or decreases in the same manne as that of modulating or message signal.the circuit used for the purpose is shown in fig below



It is a CE amplifier for carrier wave signal.Here the biasing voltage is not constant dc but is sum of the modulating signal and dc signal.we know when biasing voltage changes,this changes the amplification and the output signal will be the carrier wave varying in amplitude according to the biasing voltage.thus output will be AM signal.

Need of modulation:

Any message signal, in general, is not a single frequency sinusoidal. But it spreads over a range of frequencies called the signal bandwidth.

Suppose we wish to transmit an electronic signal, in the audio frequency range, say 20 Hz to 20kHz range, over a long distance we need to consider factors like

- Size of the antenna
- Effective power radiated by the antenna
- Avoiding mixing of signals from different transmitters
- <u>Size of antenna:</u>

- ✓ Antenna is needed for both transmission and reception
- ✓ Antenna should have a size comparable to the wavelength of the signal, atleast λ /4 where λ is the wavelength of the signal
- ✓ In the above audio frequency range,if we consider frequency = 15,000 Hz. Then λ = c/f = $3 * 10^8/15000 =$ 20000 m
- ✓ Hence, antenna length = λ /4 = 20,000 / 4 = 5000 m.
- ✓ It is practically impossible to design an antenna of height 5000m
- ✓ So the transmission frequency should be raised in such a way that the length of the antenna is within 100m which is feasible for practical purpose
- ✓ This shows that there is a need for converting low frequency signal to high frequency before transmission,which is possible by modulation.

- <u>Effective power radiated by the antenna:</u>

Effective power rated by the antenna = P = E/t

Also, E = hf= hc/ λ

Hence, P = E/t = (hc/ λ) * c/ λ =hc^2/λ^2.

P is proporational to $(l/\lambda)^2$

Hence, for good transmission, high power and hence small wavelength and high frequency waves are required,which is possible by modulation.

- <u>Avoiding mixing of signals from different transmitters:</u>

When many transmitters are transmitting baseband information signals simultaneously, they all gets mixed up

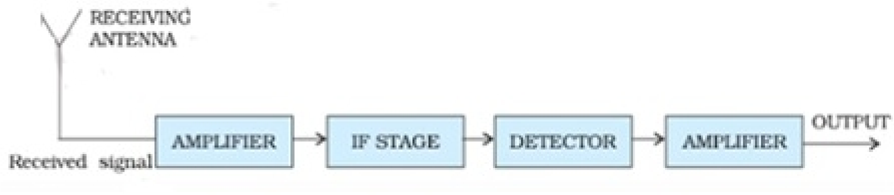
There is no way to distinguish between them.

Possible solution is communication at high frequencies and allotting a band of frequencies for each transmitter so that there is no mixing.

<u>Demodulation</u> – The process of retrieval of information from the carrier wave at the receiver is termed as demodulation.it is also called detection. This is the reverse of modulation.

Detection of amplitude modulated wave

Detection is the process of recovering the modulating signal from the modulated carrier wave. The transmitted message gets attenuated in propagating through the channel



The receiving antenna receives the signal which is then amplified.

The carrier frequency is changed to a lower frequency by Intermediate frequency (IF) stage

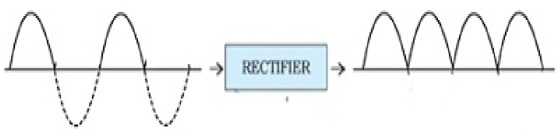
<u>Detection Process</u>:

It is then passed through the detector.

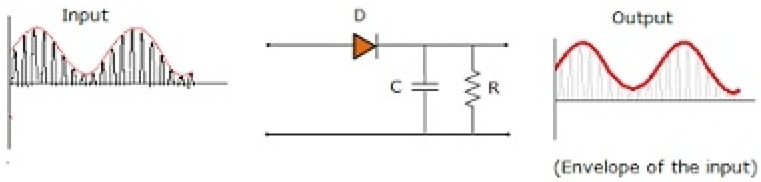
Hence, INPUT was Modulated carrier wave of frequencies ω_c, $(\omega_c+\omega_m)$ and $(\omega_c-\omega_m)$

OUTPUT is Original signal m(t) of frequency ω_m

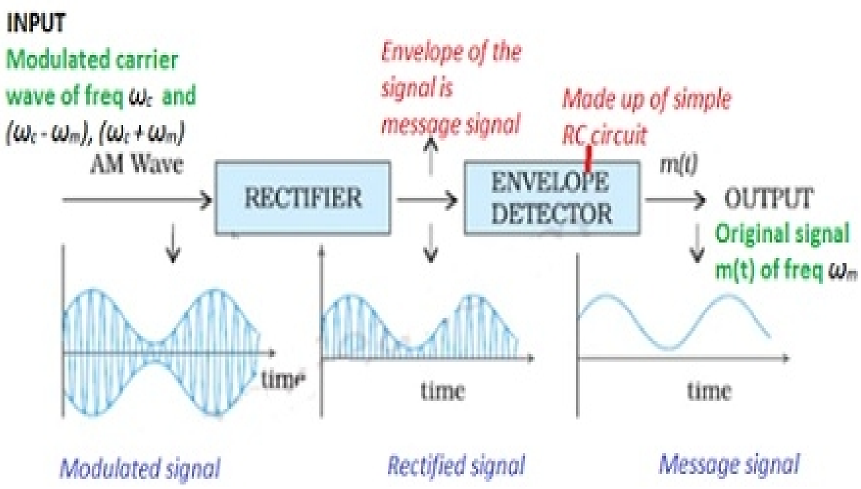
We know that <u>Rectifier gives output</u> as indicated below:the diode conducts only during forward bias.thus output will be rectified .



this then passes through RC circuit.the charging and discharging of capacitor gives final output as weak signal.The envelope detector(made of R and C) gives the envelope of the given signal.



Block Diagram for Detection of Amplitude modulated wave is shown on next page



Repeater – A repeater is a combination of receiver and a transmitter.A repeater picks up the signal from the transmitter,

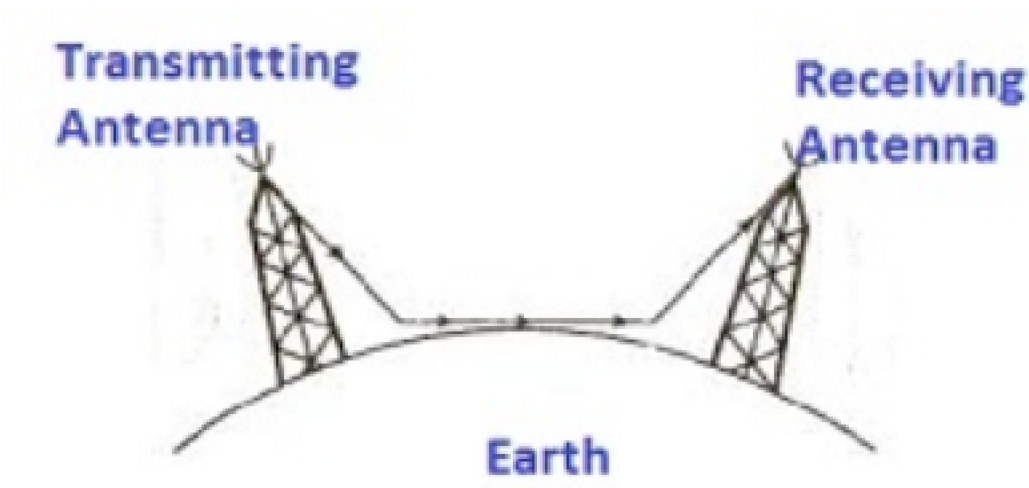
amplifies and retransmits it to the receiver. Thus repeaters are used to extend the range of communication system

Example – Communication satellite is a repeater station in space.

Propagation of electromagnetic waves

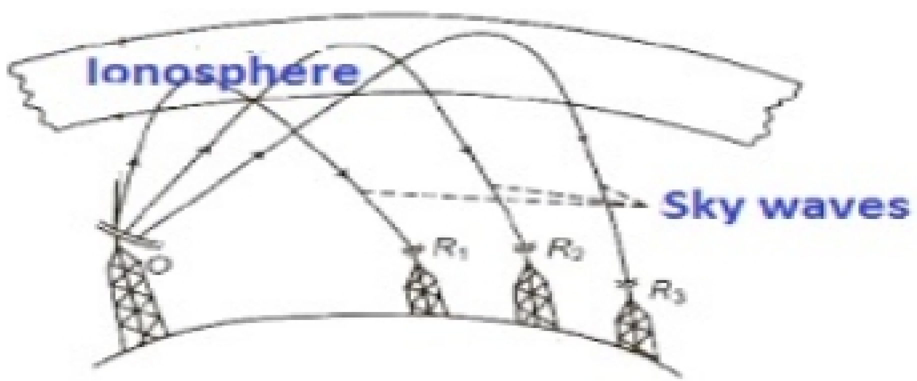
While communication using radio waves, the transmitter antenna radiates electromagnetic waves. These waves travel through the space and reach the receiving antenna at the other end. We have considered below some of the wave propagation methods in brief.

Ground or Surface wave propagation:



- In this mode of wave propagation, ground has a strong influence on propagation of signal waves from the transmitting antenna to the receiving antenna. The signal wave glides over the surface of the earth
- While propagating on the surface of the earth, the ground wave induces current in the ground. It also bends around the corner of the objects on the earth
- Due to this, the energy of the ground wave is gradually absorbed by the earth and the power of the ground wave decreases
- The power of the ground wave decreases with the increase in the distance from the transmitting station. This phenomenon of loss of power of the ground wave is called attenuation
- The attenuation of ground waves increases very rapidly with the increase in its frequency
- Thus, ground wave communication is not suited for high frequency signal wave and for very long range communication
- To radiate signals with high efficiency, the antennas should have a size comparable to the wavelength of the signal

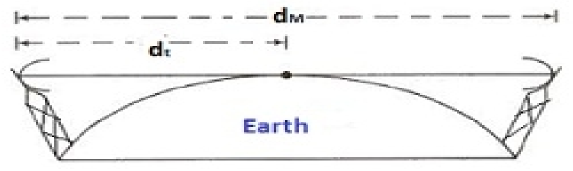
Sky waves:



- The ionosphere plays a major role in sky wave propagation. We know that the earth's atmosphere is divided into various regions like – Troposphere, Stratosphere, Mesosphere and Ionosphere.
- The ionosphere is also called as thermosphere as temperature increases rapidly here and it is the outermost part of the earth's atmosphere

- Above troposphere, we have various layers like D (part of stratosphere), E (part of stratosphere), F1 (part of mesosphere), F2 (part of ionosphere)
- The ionosphere is called so because of the presence of large number of ions or charged particles. Ionisation occurs due to the absorption of the ultraviolet and other high energy radiation coming from the sun, by the air molecues
- The phenomenon of bending of electromagnetic waves in this layer so that they are diverted towards the earth is helpful in skywavepropogation. This is similar to total internal reflection in optics
- The radiowaves of frequency range from 1710 kHz to 40 MHz are propagated in sky wave propagation

Space waves:



- The space waves travel in straight line from the transmitting antenna to the receiving antenna.
- Hence, space waves are used for line of sight communication such as television broadcast, microwave link and satellite communication
- The line of sight communication is limited by (a) the line of sight distance (b) the curvature of the earth
- At some point by the curvature of the earth, the line of sight propagation gets blocked.
- The line of sight distance is the distance between transmitting antenna and receiving antenna at which they can see each other. It is also called range of communication d_M
- The range of space wave communication can be increased by increasing the heights of the transmitting antenna and receiving antenna.
- The maximum line of sight distance (range of communication) d_M between two transmitting anternna of height h_T and the receiving antenna of height h_R above the earth is given by

$d_M= (2Rh_T)^{1/2} + (2Rh_R)^{1/2}$

Problem – A transmitting antenna at the top of a tower has a height of 32m and the height of the receiving antenna is 50m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth = 6.4×10^6 m

Solution: – Given h_T = 32m ,h_R= 50m, R = 6.4 × 106 m

$d_M= (2Rh_T)^{1/2} + (2Rh_R)^{1/2}$

$d_M= (2 \times 6.4\times 106 \times 32)^{1/2} + (2 \times 6.4 \times 106 \times 50)^{1/2}$

d_M = 45.5 Km

(b) **To find maximum distance upto which transmission can be received.** The curvature in the surface of the earth also limits the distance upto which the transmission can be received. It is because, the transmission can be received only when the receiving antenna directly intercepts the signal from the transmitting antenna.

Fig. 1.13 shows a TV antenna AB of height h. Due to curvature of the earth, the transmitted signal can be received upto a maximum distance AR_1 (or AR_2) from the antenna. Let $AR_1 = AR_2 = d$ (say). Therefore, the TV signal will be received in a circle of radius d. As said earlier, the distance d is limited by the curvature of earth. Let us derive the relation between height (h) of the TV antenna and the maximum distance (d), up to which the TV signal can be received.

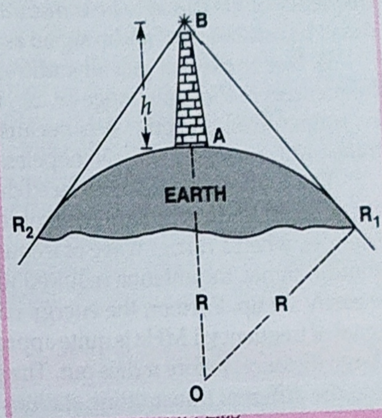


Fig. 1.13

From the right angled triangle OBR_1, we have

$$OB^2 = BR_1^2 + OR_1^2$$

Taking $BR_1 \approx AR_1 = d$, we have

$$(R + h)^2 = d^2 + R^2$$

or

$$d^2 = h^2 + 2hR$$

Since h is small as compared to the radius of the earth, h^2 can be neglected as compared to $2hR$. Therefore,

$$d^2 = 2hR$$

or

$$d = \sqrt{2hR} \qquad \text{...(1.04)}$$

The above equation gives the estimate of the distance up to which TV signals will be received, when a transmitting antenna of height h is used. It follows that to achieve larger TV coverage, transmission of TV signal should be done from a tall antenna.